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FOUNDATIONS OF BIO-PHYSICS.

On Growth and Form. By D'Arcy Wentworth Thompson. Pp. xv+793. (Cambridge: At the University Press, 1917.) Price 21*s.* net.

THIS book, at once substantial and stately, is to the credit of British science and an achievement for its distinguished author to be proud of. It is like one of Darwin's books, well-considered, patiently wrought-out, learned, and cautious—a disclosure of the scientific spirit. It is an application of some of the concepts of physical science and sundry mathematical methods to the study of organic form. "My sole purpose is to correlate with mathematical statement and physical law certain of the simpler outward phenomena of organic growth and structure or form: while all the while regarding, *ex hypothesi,* for the purposes of this correlation, the fabric of the organism as a material and mechanical configuration." "Of how it is that the soul informs the body, physical science teaches me nothing. . . . But of the construction and growth and working of the body, as of all that is of the earth earthy, physical science is, in my humble opinion, our only teacher and guide." We think that it will be difficult to justify the word "only," for in the working of the body the soul (to use the author's dualistic terminology) takes part, as when a strong emotion influences our suprarenals, and, willy-nilly, we are back in psycho-biology.

The author begins with the general "principle of similitude" first laid down by Galileo, who showed that "neither can man build a house nor can Nature construct an animal beyond a certain size, while retaining the same proportions and employing the same materials as sufficed in the case of a smaller structure." The exposition of this illustrates in a vivid way "the profound differences of physical property and potentiality which are associated in the scale of magnitude with simple differences in degree." This is introductory to a fine discussion of the rate of growth, for the form of the organism is usually a direct expression of a rate of growth which varies according to its different directions.

"The velocities in different directions tend to maintain a *ratio* which is more or less constant for each specific organism; and to this regularity is due the fact that the form of the organism is in general regular and constant."

The author has dwelt most on those aspects of organic growth which have their analogies among inanimate things. He says comparatively little in regard to the regulative phenomena which are so distinctive in the growth of organisms; and his reference to the experiments of Gudernatsch, for instance, is inadequate. Not enough is allowed, as it seems to us, for the extraordinary differences of form which may result from a slight environmental difference—for instance, in the experimentally altered fates of the indifferent larvæ of Bonellia. The final form depends on the occurrence or non-occurrence of certain differentiations, and that depends on biochemical conditions. Then again, the remarkable disturbances of form which result from the introduction of toxic substances into developing embryos (see Werber's work) suggest that form depends on more than accelerations and retardations of growth in different directions.

"The cell, which Goodsir spoke of as a 'centre of force,' is in reality a 'sphere of action' of certain more or less localised forces; and of these, surface-tension is the particular force which is especially responsible for giving to the cell its outline and its morphological individuality." In a fascinating discussion Prof. Thompson shows that cell-division and other intra-cellular phenomena may be tentatively explained as the results of a conflict between surface-tension and its opposing forces. He favours the provisional assumption that "the phenomena of karyokinesis are analogous to, if not identical with, those of a bipolar electrical field." This leads on to an interpretation of the forms of free cells as essentially dependent on surface tension. "The simple fact is that the agreement of cell-forms with the forms which physical experiment and mathematical theory assign to liquids under the influence of surface tension, is so frequently and often so typically manifested, that we are led, or driven, to accept the surface tension hypothesis as generally applicable and as equivalent to a universal law."

Utilising the facts of adsorption and Macallum's fine researches, the author shows very cleverly how apparent exceptions may prove the rule. He proceeds to the more complex problem of interpreting the forms of cells in aggregates, utilising Leduc's remarkable "artificial tissues," and he shows the courage of his convictions in attacking the problem of the formation of blastula and gastrula. In an elaborate survey of a great variety of tissues he shows that it is possible to go a long way in interpretation with the help and guidance which the phenomena of surface-tension, the laws of equilibrium, and the principle of minimal areas are at hand to supply. Attention is directed to the fact that "all possible groupings or arrangements whatsoever of eight cells (where all take part in the *surface* of the group, none being submerged or wholly enveloped by the rest) are referable to some one or other of *thirteen* types or forms," or probably fewer than thirteen, "for there is reason to believe that, out of the total number of possible groupings, a certain small number are essentially unstable, and have at best, in the concrete, but a transitory and evanescent existence."

A very interesting chapter deals with concretions, spicules, and spicular skeletons. The form of the spicule may depend simply on its chemical nature; or the inorganic solid material may be laid down in conformity with the shapes assumed by the cells, tissues, or organs; or there may be intermediate cases where the molecular forces play their part in conjunction with, and

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under the restraint of, the other forces inherent in the system. What is known as to the precipitation of calcium salts in various colloids, and as to similar phenomena, is used in the interpretation of the spicules of Sponges and Alcyonarians and the skeletons of Radiolarians and Foraminifers. There seems to be much in such formations that is not in any essential way dependent on their occurrence within living creatures.

"But every now and then we come to certain deep-seated signs of protoplasmic symmetry or polarisation, which seem to lie beyond the reach of the ordinary physical forces. It by no means follows that the forces in question are not essentially physical forces, more obscure and less familiar to us than the rest," comparable, for instance, with the formative force which Lehmann demonstrated in "fluid crystallisation." Crucial experiments are, we admit, awanting, but our faith is strained by the author's physical account of the apparently selective behaviour of certain Foraminifera which make for themselves very effective encasements of particular kinds of materials, such as sponge-spicules. We are inclined to think, also, that the author exaggerates the fluidity of Alcyonarian "species," for while his reproach may be justified in some genera, the striking feature in others is the rigid specificity, specimen after specimen like the duplicate of its predecessor, the absence of inter-grades, the clean-cut peculiarity of many of the spicular forms, and the individuality of the architecture around the polypes.

An attractive chapter deals with the logarithmic spiral which is of such widespread occurrence among animals, notably among Gasteropods. "In the growth of a shell, we can conceive no simpler law than this, namely, that it shall widen and lengthen in the same unvarying proportions: and this simplest of laws is that which Nature tends to follow. The shell, like the creature within it, grows in size, *but does not change its shape;* and the existence of this constant relativity of growth, or constant similarity of form, is of the essence, and may be made the basis of a definition, of the logarithmic spiral." From this type have evolved multitudinous diversities of form, mathematically identical, and natural selection may well be relieved of the burden of them. Of the author's explanations of horns and phyllotaxis, of the eggs of birds and the tests of sea-urchins, we have no space left to speak. We must, however, direct attention to what seems to us a slight blemish on p. 660, where the author adheres to a mechanical interpretation of the position of the spine on Bilharzia eggs, an interpretation which "destroys the chief evidence for the existence of a supposed new species of worm, a continued belief in which, among worms of such great pathogenic importance, might lead to gravely erroneous pathological deduction." We do not understand why Prof. Thompson deliberately allowed this to remain, knowing, as a note indicates, of Dr. Leiper's recent work, which does far more than assert that terminal and lateral spined eggs belong to separate and distinct species of Bilharzia. Is there not a risk that the retention of the page may "lead to gravely erroneous pathological deductions"?

With the often fanciful utilitarian interpretations of coloration and markings, of which a deliciously ironical exposition is given, the author contrasts the deep-seated adaptations of structure to mechanical efficiency, seen so well in a bone, where statical and dynamical considerations can be applied and established in detail. The book closes with a luminous essay on "the theory of transformations, or the comparison of related forms," in which it is shown, to put the matter rather roughly, how one harmonious deformation may lead from one skull or leaf to that of a related type, how trammels or lines of constraint may determine the action of the expansive forces of growth, now in one direction and again in another.

We offer Prof. D'Arcy Thompson felicitations on his masterly book. It marks a big advance in science, and it will make other advances possible. He has used his own observations and those of a hundred others to show, in a way that will surprise and delight many, what promise there is in the endeavour to carry into the study of living beings the laws and lessons of the inorganic. When first we laid the book down, we were tempted to say, "Magnificent, but not biology," but wiser reflections prevailed. Who knows better than the author what biology is and is not? We saw that he was but putting heredity and variation temporarily aside for his purpose, "to show that a certain mathematical aspect of morphology, to which as yet the morphologist gives little heed, is interwoven with his problems, complementary to his descriptive task, and helpful, nay, essential, to his proper study and comprehension of form." We would go further, and say that his argument, couched in a style that is always clear and dignified, and at times bewitchingly beautiful, has given us a fresh revelation of the unity of Nature.

J. ARTHUR THOMSON.

SCIENCE AND INDUSTRY.

The Chemistry of Dyestuffs: A Manual for Students of Chemistry and Dyeing. By M. Fort and Dr. L. L. Lloyd. ("Cambridge Technical Series.") Pp. xi+311. (Cambridge: At the University Press, 1917.) Price 7*s.* 6*d.* net.

THIS work, which has the scope of an elementary text-book, is a useful addition to the rapidly increasing number of manuals in the English language devoted to the subject of dyes and their intermediate products. The authors point out that the opportunity of development now presenting itself to the colour manufacturer in this country will lead to a greater interest in the chemistry of dyes and to an increasing demand for chemists possessing special knowledge of colouring matters. To the student equipped with

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